Shortages of Gas Supplies in the West Midlands During the Winter of 1965/66

REPORT

To:

The Right Hon. Richard W. Marsh, M.P.
Minister of Power

1. INTRODUCTION

Appointment and Terms of Reference

1. I was appointed by the Minister of Power, the Right Hon. Fred Lee, M.P., on the 14th February, 1966, to undertake an inquiry into the recent shortages of gas supplies in the West Midlands, with the following terms of reference:

> "To investigate the extent and causes of the shortages of gas supplies in the West Midlands area during the winter of 1965/66 with particular reference to the availability of plant and the breakdowns experienced, and the steps taken to restore supplies; and to report".

2. In requesting me to undertake this inquiry, the Minister expressed the wish that the main emphasis should be on the technical assessment of the causes of the breakdowns, the identification of action that could be taken to prevent similar happenings in the West Midlands or in any of the other eleven Gas Board Areas where similar plants are at work or being built, and any scope there might be for improvement in the gasmaking processes themselves or in the materials employed.

Procedure

3. I have sought evidence on the following matters:

- (i) The steps taken beforehand by the West Midlands Gas Board to estimate the probable demand for gas by their consumers in the winter of 1965/66.
- (ii) The methods and procedures adopted by the Board to ensure that sufficient plant capacity was available to meet this demand.
- (iii) The reasons why the Board's production capacity in the winter of 1965/66 turned out to be insufficient to meet demand, and the part played in this by breakdowns and delays.
- (iv) The suitability of the I.C.I. naphtha reforming process for the production of town gas.
- (v) The actions of plant manufacturers and other outside bodies concerned in the provision of gasmaking plant.
- (vi) The design, construction and operation of the plants at Tipton and Coleshill and the reasons for their breakdown.
- (vii) The steps taken to restore supplies and to minimise hardships to consumers and danger to the public arising from the gas shortage.
- (viii) The lessons to be learnt from these experiences and the prospects for the future.

4. I have conducted my inquiry by taking written and oral evidence from representatives of the West Midlands Gas Board; from representatives of Humphreys & Glasgow Limited, the main contractors to the Board for the design and construction of the reforming plants at Coleshill and Tipton; from representatives of Imperial Chemical Industries Limited, who are the proprietors of the reforming process used; from Mr. Harold Moys, who was Director

of Gas Supplies for the West Midlands Gas Board at the time of the shortages of gas supplies; from Mr. W. R. Branson, Chairman of the Scottish Gas Board, who was Deputy Chairman of the West Midlands Gas Board until November, 1965; from the Gas Council; and from the Chairman and Deputy Chairman of the West Midlands Gas Consultative Council. I am very appreciative of the frankness with which this evidence has been given and of the co-operation I have received from all concerned.

5. I have visited the gasmaking plants at Coleshill and Tipton, where I have interviewed the Design, Production and Works Engineers and maintenance and specialist staff, and inspected plant records and the engineering details of the plants themselves. I have also been provided with all the drawings and contract documents relating to these plants which I requested from the Board.

6. I am indebted to the Chairman of the Gas Council for nominating as a Technical Assessor, to advise me on the interpretation of detailed engineering evidence, Mr. J. L. van der Post, Director of the Gas Council's Engineering Research Station. Mr. van der Post's assistance has been extremely valuable and I am most grateful to him. I have also had the benefit of valuable informal advice and explanation of a number of technical matters from Mr. G. U. Hopton, the Gas Council's Co-ordinator of Research and Development.

7. I have been furnished by the British Chemical Plant Manufacturers' Association and the Gas Council with confidential reports summarising information on current problems in plant construction, which have been most helpful to me in my investigation.

8. A number of individuals have written to me to provide supplementary information and express views on various aspects of the gas shortages and associated matters, and I am grateful for their co-operation.

9. I am particularly grateful to the Joint Secretaries, Dr. L. J. Jolley (Ministry of Power) and Mr. E. J. Walters (Gas Council) for their help during my investigation and in the preparation of this report.

II. BACKGROUND INFORMATION

Primary Duty of the Board

10. The West Midlands Gas Board is one of the twelve Area Boards established by the Gas Act 1948. The primary duty of the Boards under the Act is:

> "to develop and maintain an efficient, co-ordinated and economical system of gas supply for their area and to satisfy, so far as it is economical to do so, all reasonable demands for gas within their area".

Description and Characteristics of the Area

11. The area of the Board covers about 4,800 square miles, comprising the whole or nearly the whole of the counties of Herefordshire, Shropshire, Staffordshire, Warwickshire and Worcestershire and parts of the counties of Cheshire and Leicestershire. It thus includes the industrial districts of Birmingham, Coventry, Stoke-on-Trent and the Black Country. The agricultural districts in the area are mainly on the western side.

12. There are very few coke ovens and no oil refineries in the West Midlands area. The West Midlands Board is therefore more dependent on its own production plant than are some other Gas Boards.

13. The West Midlands Board has the largest industrial load of any of the twelve Area Boards—both in quantity and as a percentage of total gas sold.

Sales of Gas

14. The number of consumers supplied by the Board and the quantities of gas sold in each of the last three years were as follows:

	Year ending 31st March, 1964			Year ending 31st March, 1965			Year ending 31st March, 1966		
	No. of Consumers at 31.3.64	Gas sold thous. therms	% of Total Sales	No. of Consumers at 31.3.65	Gas sold thous. therms	% of Total Sales	No. of Consumers at 31.3.66	Gas sold thous. therms	% of Total Sales
Domestic	1,102,056	153,731	40·4	1,123,629	177,984	42·4	1,143,369	217,500	47·5
Industrial	10,378	193,316	50·8	10,502	206,619	49·3	10,644	205,359	44·8
Commercial	41,797	29,116	7·7	41,892	30,702	7·3	40,886	31,511	6·9
Public Administration and Public Lighting	2,385	4,217	1·1	2,366	4,013	1·0	2,347	3,935	0·8
	1,156,616	380,380	100·0	1,178,389	419,318	100·0	1,197,246	457,905	100·0

Developments from 1949 to 1960

15. Up to about the year 1960 the processes available for the manufacture of gas were based almost entirely on the carbonisation of coal, with carburetted water gas plants and a few small cyclic oil gasification plants. From the date on which the gas industry was nationalised (1st May, 1949) onwards the West Midlands Board, in common with other Boards, adopted a policy of integration in its area, concentrating production in the larger and more efficient works and distributing gas in bulk from these to districts formerly served by small uneconomic works, which were then closed down. This policy was, however, limited by the low pressure at which gas was produced; the economies achieved at the larger works had to be balanced against the cost of compressing the gas sufficiently to transmit it over comparatively long distances. The whole of Birmingham, Coventry and the Black Country had been integrated by 1960. There was a separate integrated system based on Stoke-on-Trent, and some minor integrated systems unconnected with either of the main systems. At that time the highest distribution pressure in use was 20 lb/sq. in.

Developments based on High Pressure Processes

16. In 1959, the Board received permission to construct a Lurgi plant at Coleshill near Birmingham. The Lurgi process produces gas by the complete gasification of coal and operates at high pressure. The plant at Coleshill has a capacity of 40 mcfd* when butane is used for enrichment and 52 mcfd. with natural gas enrichment. The pressure at which the gas leaves the plant is about 250 lb/sq. in. It became possible therefore for the Board to visualise the construction of a pipeline system operating at a minimum pressure of 200 lb/sq. in. (a "supergrid") to convey the Lurgi gas into and eventually beyond the Birmingham area. Soon after this, a process to produce lean gas† from naphtha at high pressure (the I.C.I. reforming process) became available. Other processes to produce gas from oil feedstocks under pressure were also being developed in the gas industry's own Research Stations. The Board therefore decided in 1963 to construct at Coleshill a plant with a capacity of 50 mcfd., based on high-pressure naphtha reforming, using either Gas Council recycle hydrogenators or butane for enrichment. The Board subsequently decided to construct a similar plant at Tipton with a capacity of 100 mcfd. The orders for the reforming plants at Coleshill and Tipton were placed with Humphreys and Glasgow Ltd in 1963 and April 1964 respectively. The Board later ordered further oil reforming plants but these were not planned to come into operation until after the winter 1965/66.

17. The Board joined with other Gas Boards in the Gas Council's scheme for importing liquefied natural gas (methane) from Algeria. The quantity which the Board agreed to take was 12½ mcfd. and a branch from the national methane pipeline into the Coleshill Works was laid so that the methane could be used to enrich the Lurgi gas. This became available in late 1964.

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*mcfd: million cubic feet per day.

†The gas produced by this process and the gas made from coal in the Lurgi process have calorific values lower than that required for distribution as town gas. Hence they require enrichment by the addition of a gas of higher calorific value than town gas, such as butane or natural gas. Enriching gas can also be made from naphtha by processes developed by the Gas Council—the Recycle Hydrogenation process and the Catalytic Rich Gas process.

18. Thus all the high-pressure town gas supplies available to the Board are produced by blending lean gas from the Lurgi and naphtha-reforming plants with a suitable rich gas to give normal town gas with a calorific value (in the West Midlands area) of 500 B.t.u. per cubic foot. Neither the lean gas nor the gas used for enrichment can be supplied to consumers by itself. They must be mixed in the correct proportions to produce gas with the declared calorific value and suitable combustion characteristics; otherwise consumers' appliances will not operate satisfactorily.

19. With the installation of the high pressure processes in mind, the Board planned to extend the supergrid to the whole of its area. By the end of March 1965, the supergrid extended over most of the Board's area; the total length constructed by that date was 138 miles. A control room has been constructed at the Board's headquarters to monitor and control the movement and pressure of gas in the supergrid and associated local grid mains and the operation of gas-making stations.

20. The I.C.I. process and the processes developed by the gas industry in its own Research Stations produce gas from oil feedstocks at a much lower cost than gas can be produced from coal by carbonisation or by the Lurgi process.

Authorisation of Capital Investment

21. The Gas Act, 1948, Section 1 (5) provides that in carrying out any measures of reorganisation and works of development which involve substantial outlay on capital account, every Area Board shall act in accordance with a general programme settled from time to time with the approval of the Minister of Power, and the Minister shall consult with the Gas Council before approving any such programme. In accordance with this provision a Capital Development Programme is submitted by each Board annually to the Minister of Power and to the Gas Council. These programmes cover the year current at the time of submission and a period of five years ahead. They include statements of specific projects for the installation of gasmaking plant or distribution schemes costing over £100,000 and are the basis on which the Minister of Power authorises the total amount of capital investment by any Board in a year and the major projects proposed by the Board.

22. Representatives of the West Midlands Board have stated that the Board has never found it necessary to defer proposals for the installation of new gas-making plant at Coleshill and Tipton or for sections of the supergrid through any refusal by the Minister to authorise the projects or the capital investment required.

III. FORECASTING DEMAND

Methods of Forecasting

23. I have received from the Board an explanation of the methods used by it to forecast the future demand for gas. These methods are based on:

(i) extrapolation of past experience so far as the traditional uses of gas are concerned, i.e. cooking, water heating and laundering equipment in domestic premises, and the commercial demand;

(ii) an assessment of the industrial demand based on the National Plan, the level of industrial activity and competition by alternative fuels;

(iii) forward estimates of the sales of gas fires and central heating installations and market research to establish how much gas these will use during a year and on a peak day.

24. The Board then forecasts the total quantity of gas which will be sold during a year and the quantity which will be required on a peak day. The estimate for the year is based on average weather conditions over the last hundred years and its main use is to estimate revenue. The estimate for the peak day is based on a week with an average daily temperature of 24°F., which is considered to occur not more than once in twenty years; it is used to determine the capacity of gas-making plant required by the Board. The Board reviews the forecasts at frequent intervals, in the light of current experience. The following table shows the Board's forecasts of demand and the production capacity planned to meet it.

PEAK DEMAND AND ASSOCIATED PRODUCTION CAPACITIES

million cu.ft./day

1. As Forecast in the 1964 Capital Development Programme

Winter of Year	Planned Production Capacity	Forecast Demand at 24°F.	Production Surplus on Peak Day	Surplus with Allowance for Stock Depletion
1964/5	410·7	398	12·7	24
1965/6	445·8	441	4·8	14
1966/7	491·0	482	9·0	17
1967/8	515·7	515	0·7	7
1968/9	540·4	540	0·4	6

2. As Forecast in the 1965 Capital Development Programme

Winter of Year	Planned Production Capacity	Forecast Demand at 24°F.	Production Surplus on Peak Day	Surplus with Allowance for Stock Depletion
1964/5	416·1	399	17·1	28
1965/6	485·5	450	35·5	45
1966/7	536·3	524	12·3	18
1967/8	590·1	571	19·1	23
1968/9	651·9	611	40·9	44

3. As Forecast in the Revised 1965 Capital Development Programme

Winter of Year	Planned Production Capacity	Forecast Demand at 24°F.	Production Surplus on Peak Day	Surplus with Allowance for Stock Depletion
1964/5	412·0	422	−10·0	0
1965/6	489·3	482	7·3	15
1966/7	554·4	546	8·4	13
1967/8	620·5	604	16·5	19
1968/9	745·6	654	91·6	93

25. The Board has since calculated that the demand at 24°F. during the winter 1965/66 would have been 469 mcfd if there had been no shortage of gas. It is thus apparent that the forecasting methods used gave a reasonably accurate estimate. In its 1964 Capital Development Programme, the Board stated that its policy was to provide the production capacity necessary to meet the expected demand on a maximum day at 24°F. without nett loss of holder stock but also without reserve of plant. I comment on this in para. 30. The additional quantity of gas from "stock depletion" would not be available for a peak demand for more than a day or two.

26. In the course of my investigation I have considered only the forecast of gas output on a peak day because the forecast of total gas output in a year is not relevant to the adequacy of gas supplies over any particular shorter period.

27. For the purposes of day-to-day operation the Board receives each morning a weather forecast. The Board then estimates the gas demand for that day and for the following day and decides on the plants which should be operated to meet it.

Review of Forecasts in March 1965

28. In March 1965, the estimated peak demand at a temperature of 24°F. was reached when the actual temperature was 29·7°F. In consequence the Board reviewed and increased the forecasts of gas demand given in the Capital Development Programme dated February 1965. The Board's analysis of the reasons why demand for gas was outrunning their forecast showed that these were as follows:

(i) Sales of domestic space heating appliances, which normally fall off after Christmas, had remained much higher than expected during the three months January to March, 1965.

(ii) Market research by the Board had shown that a higher proportion of gas fires were being installed in main living rooms—thus increasing the demand

(iii) The Board had been able to retain some industrial sales it had expected to lose.

In particular, the forecast peak demand during the winter 1965/66 was increased from 450 to 482 mcfd. Forecasts for the following years were increased on somewhat the same scale.

IV. PLANNED AND ACHIEVED CAPACITY

29. In 1963 the production capacity of the Board was 353 mcfd, mainly carbonising plant and carburetted water gas plant. It included small amounts of gas from low-pressure oil gas plants, coke oven gas and mine drainage gas. As all these gases were made at atmospheric pressure it would have been uneconomic to transmit them over long distances. In 1963 the Lurgi plant mentioned in paragraph 16 came into operation. The reforming plants at Coleshill and Tipton mentioned in paragraph 16 were due for completion in November 1964 and November 1965, respectively.

30. In the Board's 1964 Capital Development Programme the production capacity planned for the winter 1965/66 was 445·8 mcfd including the Coleshill and Tipton reforming plants and allowing for the closure of some old carbonising

plants. As shown in the table attached to paragraph 24, this capacity allowed a margin of only 4·8 mcfd (just over 1 per cent) over the estimated demand on the peak day. In my opinion the Board's policy at that time in respect of contingencies was imprudent, and I am glad to note that it was changed in the following year. By that time, however, it was too late to have much effect in the winter of 1965/66.

31. In order to provide for the increases in the forecast peak demand mentioned in paragraph 28, the Board postponed planned closures of plant and took steps to increase the capacity of other plants and by this means increased the planned production capacity for the winter 1965/66 to 489 mcfd. The Board considered a number of other means of increasing capacity (including the installation of a butane reforming plant) but could not adopt them mainly because of the short time available. In fact, the total production capacity would have been 496 mcfd if all of the Board's plants had been in operation, as follows:

	mcfd
Continuous Vertical Retorts	138
Water Gas and Producer Gas Plants	116
Other Low Pressure Plants	25
Purchased Gas	13
Lurgi Plant (including 12 mcfd Methane)	54
Coleshill and Tipton Reforming Plants	150
	496

32. The plant at Coleshill was due to be completed by 30th November 1964. Completion was a little late and the plant began making lean gas in January 1965. It was, therefore, available for the winter 1965/66, butane or methane being used for enrichment.

33. The dates on which the three streams of the high pressure oil reforming plant at Tipton were scheduled for completion and the dates on which they were actually completed are as follows:

	Date scheduled for completion	Actual completion date
1st Stream		
Lean Gas	2/11/65	30/10/65
Hydrogenation enrichment		not working during winter 1965/66
2nd Stream		
Lean Gas	between 2/11/65 and 16/11/65	19/12/65
Hydrogenation enrichment		not working during winter 1965/66
3rd Stream		
Lean Gas	16/11/65	25/3/66
Hydrogenation enrichment		not working during winter 1965/66

The hydrogenation enrichment stages were not vital for the supply of gas to the grid by these plants, provided that other enrichment was available.

34. Realising the danger of the plant being late the Board and the contractors did everything they could to ensure that it was completed on schedule. However, only one stream was making gas before Christmas 1965, the second on the 20th January 1966, and the third well after the crisis. Apart from breakdowns the Board was not, therefore, able to achieve the total production capacity of 496 mcfd mentioned in Paragraph 31. The consequences of the situation in November 1965 and January 1966 are described in detail in Section VI of this report.

V. DESCRIPTION OF PLANTS

General

35. The following brief description of the high-pressure reforming plants at Coleshill and Tipton provides a background to the evidence I have received on the breakdowns which led to the gas shortages. The plants are highly complex, and in describing them I have been concerned mainly to draw attention to those features which have some relevance to their special advantages to the gas industry and their special operational problems.

36. These plants are high-pressure continuous catalytic steam-naphtha reformers which manufacture a lean gas for enrichment to town gas. The production of the enriching component of the town gas, by hydrogenation of additional naphtha in a separate section of the plant, was also provided for in their design; equipment for this was already built when they were in operation in the winter of 1965/66. The hydrogenation-enrichment stage, however, was not operational and "cold enrichment" with butane was employed to bring the calorific value of the lean gas up to the required standard of 500 Btu/cu.ft. The following description is therefore not concerned with the hydrogenators.

37. The function of the reformers is to convert a light petroleum distillate fraction (naphtha) to a lean gas consisting mainly of hydrogen and methane, by passing a mixture of naphtha vapour and steam over a special catalyst at about 750°C. Early plants of this type, built up to about 1963, operated at pressures of about 150 lb/sq. in., but the "second generation" plants built since then have been designed for pressures of about 400 lb/sq. in. (more than 25 atmospheres). The Coleshill and Tipton plants belong to the second generation—that at Coleshill being one of the first of this type designed for the U.K. gas industry. The advantages of the higher pressure are a slightly higher thermal efficiency, a lean gas of higher calorific value, a higher output per unit, and an outlet pressure high enough to enable the gas to be supplied direct to the supergrid.

38. The gasmaking process consists essentially of the following stages:

(i) purification (desulphurisation) of the naphtha feedstock
(ii) the catalytic reforming stage.
(iii) treatment of the reformed gas to remove carbon monoxide and some carbon dioxide.
(iv) enrichment with butane or other rich gas.

Appendix 1, (Fig. 1) shows a flow sheet for the complete process, apart from hydrogenation enrichment. Figs. 2 and 3 are more detailed flow diagrams for the

Coleshill and Tipton plants, showing points of difference between them, and the items of equipment involved in breakdowns during the period of gas shortage. The plant has, of course, a multitude of pumps valves and controls which are not shown in these diagrams, although they make up a large proportion of the total plant investment.

Desulphurisation

39. Desulphurisation of the naphtha is effected by passing it, mixed with a "recycle" stream of hydrogen—rich gas, through vessels in which the total sulphur content of the naphtha is reduced to below 0·5 parts per million. The recycle gas used in this stage is part of the finished lean gas made in the process, after removal of carbon dioxide with a solution of potassium carbonate.

40. The Coleshill and Tipton plants were built with considerably larger recycle streams than would have been required for desulphurisation alone, to provide additional recycle gas for the hydrogenation-enrichment stage, which requires a similar gas. Consequently while the plants were in use without hydrogenation enrichment, only part of the recycle gas was passed to the desulphurisers and the remainder was returned to the finished lean gas stream.

41. On its way to the desulphuriser the mixture of naphtha and recycle gas is passed through a multitubular superheater in the "convection bank" heated by hot waste gases from the reforming furnace. Another set of heat-exchange tubes in the convection bank superheats steam which is then mixed with the desulphurised naphtha vapour. The mixture then passes to the reformer tubes. Figures 2 and 3 show that slightly different arrangements of naphtha and steam superheaters in the convection bank were used in the Coleshill and Tipton plants.

Reforming

42. The superheated steam-naphtha mixture is passed downwards through tubes containing the reforming catalyst in the reforming furnace. These tubes are each about 30 ft. long and 5 in. diameter, made of cast nickel-chromium (25:20) alloy steel. Each reforming furnace contains about 110 of these tubes, arranged in four rows and with their inlet and outlet ends connected to "header" pipes. The connections are made through narrower "pigtail" tubes of a more or less hairpin shape which are sufficiently long to provide flexibility to take up thermal expansion and contraction of the reformer tubes. The headers are also supported in such a way that they can expand and contract without constraint.

43. The furnaces containing the reformer tubes are brick-lined chambers in which a separate supply of naphtha is burned with air at atmospheric pressure at a number of atomising burners in the furnace roof. The brick walls are maintained at a temperature of 900–1,000°C and the reformer tubes are heated by radiation from them. The hot waste gases leaving the furnace pass through the "convection bank" in which they give up most of their heat to the naphtha and steam superheaters, air heaters and waste-heat boilers before passing to the stack.

44. The crude reformed gas, containing surplus steam, leaves the reformer tubes at about 750°C, via the pigtails and outlet headers, which are outside the

furnace and enclosed in the header box. The composition of the gas is approximately:

Hydrogen	60	per cent by volume
Carbon monoxide	10	,, ,, ,, ,,
Methane	14	,, ,, ,, ,,
Carbon dioxide	16	,, ,, ,, ,,

The outlet headers are horizontal alloy-steel pipes about 40 ft. long and 8 in. diameter, along which the ends of the pigtails are connected by welded joints. The headers are at a temperature of about 730°C during operation. From each header the gas passes to the primary waste-heat boiler, in which steam is generated and passes to the common steam drum at a pressure of 470 lb/sq. in. The feed water to the boilers is supplied through electrically driven multi-stage pumps.

Conversion

45. The reformed gas, now at a temperature of about 400°C, passes to a catalytic carbon monoxide conversion stage. Here part of the unreacted steam reacts over a special catalyst with the carbon monoxide in the gas to form additional hydrogen and carbon dioxide. The converted gas has the approximate composition:

Hydrogen	62	per cent by volume
Carbon monoxide	3	,, ,, ,, ,,
Methane	13	,, ,, ,, ,,
Carbon dioxide	22	,, ,, ,, ,,

46. The gas is further cooled in a waste-heat boiler and finally in air-cooled finned tubes. As the gas is cooled the remaining process steam in it condenses. The gas is finally dried and is then ready for enrichment and distribution to the supergrid.

Recycle Gas

47. Part of the converted lean gas is diverted from the main stream and stripped of carbon dioxide by washing with potassium carbonate lye in a separate section of the plant, consisting of two packed towers. In one tower the gas is scrubbed with the lye, while in the other the lye is stripped of carbon dioxide and returned to the system. The carbon dioxide is blown to waste.

General Engineering Considerations

48. A complete reforming plant is normally constructed in several "streams", which may be completely separate or may have some equipment in common. Where the streams are separate, each has its own desulphurising plant, reformer furnaces, conversion and carbon dioxide removal vessels, and the necessary boilers and heat exchangers, pumps, etc. At Coleshill there are two streams, each with an output of 25 mcfd of lean gas; at Tipton there are three streams, each with an output of 33 mcfd.

49. At Coleshill it was decided that standby equipment for items such as pumps would be on the basis of one common standby serving both streams. At Tipton, each stream has its own independent standby arrangements. There is clearly scope for economy in plant investment by sharing certain items of process equipment between two or more streams, but this has the disadvantage that trouble on one stream could cause a shutdown of the whole plant. The

present tendency is therefore towards complete independence of the separate streams. It is also possible to reduce the total capital cost by reducing the number of streams and increasing their size, but this carries the risk of a greater loss of production should one stream fail.

50. The boilers in the convection bank of the flue gas section and the process gas waste-heat boilers are very highly rated, with low water capacity and high steam-release rates. The instantaneous output of steam is very sensitive to fluctuations of temperature, pressure and flow rate in the process gas streams, and it is possible for steam surges to occur. These can be self-augmenting and can lead to priming of the boiler or to water tubes running dry. The very close integration of the steam generating system with the process thus exposes it to conditions which are much more severe than in conventional steam engineering and need special attention to design and control.

51. Throughout the plant, there is an elaborate and largely automatic system of instrumentation and control of flow rates, temperatures and pressures. A number of automatic "trips" are built into the system, to shut off certain services in the event of an instrument indicating conditions outside prescribed limits. The purpose of these trips is to prevent dangerous conditions developing, and in this respect they perform a valuable function; but they can occasionally lead to a complete automatic shutdown of the plant as a result of malfunctioning of an instrument, or of some other condition which could have been rectified manually without danger.

52. I have inspected the plants at Coleshill and Tipton and discussed their engineering and operational problems with design and operating engineers and maintenance and operating staff. My impression is that these plants are, in most respects, excellent examples of modern chemical engineering and that a great deal of knowledge and skill has gone into their manufacture at all levels. Nevertheless they employ process conditions which are on the threshold of present knowledge and experience and involve an element of pioneering in techniques, materials and methods of construction. This situation has to be faced, and for some time to come it will be prudent to accept the possibility of occasional breakdowns. The engineers and other staff whom I met impressed me as fully able and determined to master novel problems in running new types of plant. I have confidence that the fund of experience and skill which they are building up will enable the reliability of these plants to be progressively increased.

VI. THE GAS SHORTAGES IN THE WINTER OF 1965/66

The Gas Shortage in November 1965

53. Following the measures taken earlier in 1965 to provide the maximum possible production capacity for the winter months, the Board had plant with a total rated output of 396 mcfd available at the beginning of November. This consisted of 292 mcfd of low-pressure gas from 14 works equipped mainly with coal carbonisation and water-gas plants, and 104 mcfd of high-pressure gas from the Coleshill works. The high-pressure gas was provided by the Lurgi plant (54 mcfd including 12 mcfd of imported methane for enrichment) and the 50 mcfd naphtha reformer; the latter was without its naphtha-based hydrogenation enrichment, and provided lean gas for enrichment with butane or natural gas.

54. The difficulties in the period 15th–17th November arose from the coincidence of a period of exceptionally cold weather, beginning on the 13th November, with the unavailability of some gasmaking capacity as a result of breakdowns and other problems. The most serious was a breakdown of the high-pressure reforming plant at Coleshill, but shortages of capacity at other works were contributing factors.

55. I have been assisted in my examination of the circumstances of the gas shortage in November by a detailed report prepared for the Gas Council by a special Panel immediately following the shortage. Many of the details which follow are taken from this report. Others are from the Board's own reports on the shortages and from information given me directly by them.

56. At the beginning of the cold spell, some 19 mcfd of the rated output of coal-gas and water-gas was not available because of a variety of unexpected breakdowns, repairs and manpower problems, including shortages of water-gas plant operators and bricklayers. Also over the period 9th–14th November half of the Lurgi plant capacity was shut down for a change of catalyst. This was a routine operation and the Lurgi plant was fully back in commission by the 14th November. There was no subsequent shortage of Lurgi gas.

57. The reforming plant at Coleshill had been operating at a somewhat reduced output for some weeks, while awaiting repairs to a feedwater heater. This meant that one of its 25 mcfd streams was providing only 18 mcfd.

58. Altogether, the Board was short of 46 mcfd of its rated output on the 12th November, and was still short of 26 mcfd on the 14th. Nevertheless it appeared at that stage that the demand of 388 mcf forecast for Monday the 15th could be met with the aid of gas from storage, coupled with maximum output from both high and low-pressure plants.

59. At 11 p.m. on the 14th November, however, the 25 mcfd reformer stream which had been running at full output broke down without warning. The cause had not been located by 7 a.m. the following morning and there was no certainty when production could be resumed. Meanwhile the exceptionally severe weather and heavy demand for gas continued and the Board was faced with a situation in which gas stocks were rapidly approaching the minimum consistent with safety.

60. Press and radio statements were issued on Monday morning asking all consumers to economise in the use of gas, and explaining the Board's difficulties; district gas pressures were reduced as much as possible. The effect however was not sufficient to retrieve the situation, and the Board's officials proceeded on the 16th to visit individually some 70 factories in its Central area and 45 factories in the Stoke-on-Trent area to cut off gas supplies. Other factories were asked to reduce consumption and where possible to stop using gas. The largest industrial supply in the West Midlands is taken by the motor car industry and the second largest by the potteries, and cuts were spread over these two industries as fairly as possible. The Board was bound to ensure the supply of gas to domestic consumers because the margin for manoeuvre in the case of domestic supply is limited by the need to avoid extinguishing pilot burners with the risk of subsequent escape of unburnt gas into dwellings. The Gas Council's Panel of inquiry was satisfied that it was not practicable to reduce district pressures any further.

61. The drain on stocks was halted at a stock level 30 mcf lower than ever before in the Board's history. During the following day, with the coming of milder weather, stocks were built up to an acceptable level and industrial consumption levels were restored in consultation with managements.

62. The cause of the breakdown at Coleshill was identified as blockage of the naphtha vaporiser/superheater, due to carry-over of liquor containing potassium carbonate from the carbon-dioxide removal plant. This possibility had not been foreseen in the design of this or other similar plants. The blockage was cleared by 6.30 a.m. on the 16th November, and re-commissioning was complete at 11 a.m. on the 17th November.

The Gas Shortage in January 1966

63. The capacity of plant available to make low-pressure gas in January 1966 was the same as in November (292 mcfd from 14 works) and repairs had been completed at Coleshill so that this works had an effective capacity of 104 mcfd of high-pressure gas. On the Board's calculations, however, the supply of gas required for a maximum peak day at 24°F was 482 mcf. The full capacity of 100 mcfd at the Tipton works was therefore required to provide security of supply. The shortage of gas in January was the result of inability to complete and commission the whole of the planned capacity of the Tipton plant before the period of cold weather which extended from the 10th to the 20th, coupled with a series of breakdowns of high-pressure reforming plant at both Tipton and Coleshill works. Under pressure of the shortage the second 33 mcfd stream at Tipton was brought into operation on the 20th January, but there was no hope of bringing in the third stream in time to influence the situation.

64. Even without any breakdowns the gas available would have been only 429 mcfd until the 20th January and 462 mcfd thereafter without the third stream, and any prolonged spell of severe weather was bound to place the system under strain.

65. Temperatures from the 10th to the 21st January were low; in fact, average day temperatures below 30°F occurred on the 14th (27·5°F), 15th (29°F), 18th (25·5°F) and 19th (25°F).

66. The situation at Tipton on the 10th January was that the first 33 mcfd reformer stream, which had started to supply gas on the 29th November was out of commission for rectification of a fault in the primary waste-heat boiler, while the second and third stream were still not completed. On that day, with an average temperature of 31°F., the Board had to reduce district pressures in all regions pending completion of work on the boiler.

67. The plant was re-started during the afternoon of the 11th. Within a few hours the operating staff noticed erratic steam flows, and smoke from the lean gas coolers. The cause was not immediately apparent, and the action taken was based on two alternative possibilities: priming of the main waste-heat boiler, and mechanical trouble with the lean-gas coolers further downstream. Naphtha supplies to the plant were reduced immediately. Subsequent events and inspection of records have shown that the instability was boiler priming, due to contamination of the feed water with potassium carbonate.

68. The resulting carry-over of water into the reformer tubes and outlet headers subjected them to rapid cooling, which by reason of the brittleness of

the high-alloy steel used in the construction of the headers caused one of them to fracture.

69. When the plant first started the condensate from the carbon dioxide removal plant was run to waste. When the hydrogenator is not working there is a possibility of carbonate carrying over in this condensate. As no trouble had hitherto been experienced it was decided to use this condensate and return it to the process. Boiler water was monitored for impurities once a day in the morning. That afternoon, during a maintenance operation, a valve was operated incorrectly allowing about 100 gallons of carbonate to carry over. This was not detected at the time. After the accident it was estimated that the concentration of carbonate in the boiler drum rose to about 4000 p.p.m. (about twice the specified limit) and this was the cause of the prime.

70. The operating personnel, under the direction of the contractors' commissioning engineer, who was in charge of the plant during this period, acted promptly and correctly in dealing with the serious risk of fire and explosion. Largely as a result of the naphtha supplies having been turned off, the escaping gas when it ignited caused only a minor fire which was extinguished without personal injury or damage to equipment.

71. It was not possible to restore production from this stream during the period of gas shortage, in spite of a very energetic co-operative effort by the Board's engineers and works staff, the main contractors and a number of sub-contracting firms. Two replacement headers were manufactured, delivered and installed by mid-day on Monday, the 24th January—an operation in which welding went on continuously round the clock and the completed job was found fully satisfactory. This was a remarkable achievement and reflects great credit on the manufacturers and all concerned. Further tests and repairs and replacements of other equipment, however, and a labour dispute which arose on the site, slowed down the final reinstatement. The plant was brought back into commission on the 6th February and resumed supply of gas to the grid on the 8th.

72. The second 33 mcfd stream at Tipton was put to work on the 20th January. It had to be shut down next day because of a hot spot in the primary waste-heat boiler. This was rectified, and the plant was able to supply gas to the grid by the evening of the 25th. Thereafter the plant produced some gas every day but did not reach full output during the period of shortage. There were three further interruptions, two due to electrical faults and one to a cracked reformer tube, but the Board do not regard these as having delayed restoration of supplies to consumers.

73. The high-pressure reformers at Coleshill were in full production from the 10th to the 19th January, and in fact were run at outputs above their rated capacity. During the night of the 19th/20th, however, both streams of this plant were forced to shut down because of failure of the boiler feed-water pumps. The water supply was restored after 15 hours by the Board's maintenance staff, and gas production was resumed on one 25 mcfd stream. The other stream suffered a fracture of its naphtha superheater. It remained out of commission until the 28th January.

74. The Lurgi plant at Coleshill operated with great reliability and was run at above its rated capacity throughout the emergency. Satisfactory outputs of gas were also maintained from the low-pressure plants in the Board's system.

75. The sequence of plant shortages and breakdowns over the period 10th–30th January, which led to the Board's shortage of gas, was thus more complex than the November shortage. Besides extending over a longer period it involved more severe shortfalls in production and uncertainties as to when resumption of supplies could be expected. I am satisfied that under these extremely difficult conditions no effort was spared by the Board, its staff and its contractors to restore the situation and to provide the maximum possible supply of gas to consumers consistent with safety. Equally I have been impressed by the co-operation of industrial gas consumers, who bore the brunt of the shortage by accepting cuts in gas supplies which involved them in substantial and expensive losses of production. It is evident to me that established relations between the Board and consumers were good and that the West Midlands Gas Consultative Council played a most valuable part in mitigating the difficulties of the situation and ensuring that the burden on consumers was shared as fairly as possible.

76. From information provided to me by the Board, it appears that the aggregate shortfall in gas supplies from works in the Central Area over the period 10th–28th January was about 700 million cubic feet. As far as possible, industrial consumers were given warning of the possibility of cuts in supplies, and efforts were made to avoid cutting supplies to firms which had suffered in the November shortage. Warnings and severe pressure reductions were in force from the 10th January, but it was not found necessary actually to cut off any supplies to industry until the 17th, when 67 firms taking a total of 27 mcfd were asked to stop using gas. These supplies were restored the following day but on the 20th January, as a result of the breakdown at the Coleshill works, cuts had to be imposed on 424 firms taking 106 mcfd. Supplies to some firms in the south-western and south-eastern regions and the Redditch area were also restricted or stopped, and 111 firms using 8·5 mcfd in intermittent and continuous kilns in the Stoke area were deprived of gas. Supplies to the Stoke area were progressively restored over the 21st–23rd January, but 405 firms in the Central area requiring 61 mcfd, including the motor industry, were still without gas on the 25th. Thereafter supplies were progressively restored to all consumers and by the 29th January it was possible to advise them that they could expect all their requirements to be met.

VII. ENGINEERING ASPECTS

Organisation of Design and Construction

Imperial Chemical Industries Ltd.

77. The high-pressure naphtha reforming process used at Coleshill and Tipton is based on research by I.C.I. dating from 1928. In 1962, following the construction of two pressure reformers at Heysham, I.C.I. decided to license certain selected contractors to build plant based on their patents. There are now six licensed firms, including Humphreys and Glasgow Ltd. Four contractors are permitted to offer the process for making town gas in the U.K. The number of plants is growing rapidly, so that an exact count is never up to date. The approximate numbers of units in the U.K. gas industry at the time of the West Midlands crisis were 50 in commission, with a further 50 on order.

78. The agreement under which Humphreys and Glasgow are licensed provides that while I.C.I. furnish information on process engineering, they assume no responsibility for the mechanical details of the vessels, etc., which contain the process. Further activities of I.C.I. beyond the scope of the agreement include the services of their Licensing Department, whose function is to see that licensees' information is up to date and that important technical problems receive attention when they arise. I.C.I. have also provided some training for the operating staff of organisations which have purchased reformers using their process.

79. I have been informed that I.C.I. gave full details of the mechanical design of its first pressure reformers to its licensees. These plants operate at pressures of about 150 lb./sq. in. and have given satisfactory service, with an availability which has now reached 97%. The mechanical design was then developed by the licensees for operation at higher pressures. I.C.I. no longer build reformers themselves but employ the licensees to build plant for them.

Selection of Tenders by the West Midlands Gas Board

80. The contracts for both Tipton and Coleshill plants were placed with Humphreys and Glasgow Ltd., on the basis of competitive tenders. This firm had long experience of constructing plants for the gas industry and I am satisfied that the Board made no error of judgment in selecting them for the contracts.

Conditions of Contract

81. Both the Coleshill and the Tipton plants were tendered for on a lump sum basis, with quoted delivery times of about 19 months. There has since been a considerable expansion of business in the chemical plant industry and in consequence contractors are now reluctant to tender for any further plants on this basis, due to overloading of manufacturers and fabricators. Contract completion time has now lengthened to more than 27 months.

Organisation of the Board

82. The organisation of gas supplies in the West Midlands prior to January 1966 is detailed in Appendix 2. The functions of the relevant officers were as follows:

(i) The Director of Gas Supplies was in charge of the production of gas throughout the Area, and was responsible for the ordering and installation of new plant in accordance with the Board's capital investment programme.

(ii) The Development Engineer was responsible for advising on the choice of processes used by the Board, the specification to which enquiries were sent out, and the vetting of tenders submitted.

(iii) Mechanical and electrical details were vetted by the Board's Mechanical and Electrical Engineer.

(iv) The Station Engineers were responsible for progressing the contractors' work at site.

(v) The Construction Engineer was in charge of the work which the Board itself carried out. This included storage systems for naphtha, butane and water, effluent disposal systems, and facilities for fire-fighting.

83. The Board decided as a result of experience at Coleshill to appoint a full-time Project Manager for Tipton, with direct access to the Board. I have received evidence that this appointment did much to ensure that all possible steps to expedite the plant were taken.

84. At the time of this appointment the Board gave instructions that no further alterations to the design of the plant were to be allowed.

85. I have been satisfied that both the Board and Humphreys and Glasgow Ltd. were fully conscious of the need for a concerted effort to avert the risk of a gas shortage in the winter. In the event, the first stream at Tipton was completed on the 30th October, 1965, ahead of schedule, and first sent gas into the grid on the 29th November. In view of the problems involved, this was something of an achievement and worthy of commendation.

86. Following the experience of last winter, the Board's engineering organisation has been modified. Among other changes, a Project Department has been set up.

Construction and Operation of Plants

87. I have been concerned to know to what extent the Tipton plant was delayed, and what were the causes of delay. Secondly, I have tried to find out whether the breakdowns experienced were the result of mistakes in design or operation.

Delays

88. The three streams at Tipton were ordered in April 1964 for delivery in 19 months. The first stream went to work on 29th November 1965, the second on 20th January 1966, and the third in March 1966.

89. Evidence has been given that plant to the same design as at Tipton took 23 months to complete during the period in question, and that the effort to get even the first stream of the Tipton plant finished on time meant diverting some equipment ordered for other plants. At the time of the crisis contractors were quoting a delivery date of 27 months for similar plant, and this time has since lengthened.

90. The Gas Council has investigated the widespread delays in completion of reformers which have occurred throughout the gas industry, and in which all the main plant contractors have been involved. The main reasons found were:

(i) late delivery of components by manufacturers,

(ii) alterations in design specifications after acceptance of contracts (this was avoided at Tipton, as noted in para. 84 above),

(iii) labour troubles at sites (in this connection, Humphreys and Glasgow Ltd. have informed me that they had no significant trouble at Tipton, although elsewhere their experience had been less happy. Some men refused to work overtime following the header failure, but this did not affect the crisis).

91. An inquiry carried out by the British Chemical Plant Manufacturers' Association has shown that late delivery of components by sub-contractors has been due mainly to overloading of manufacturing capacity at fabricators' works. Until this situation is remedied, delay in deliveries are inevitable.

Short Cuts

92. As a result of the November crisis the Board asked Humphreys and Glasgow to give priority to the first stream and common services at Tipton, and to take short cuts where possible. As a result, some components which were not regarded as essential were omitted. These included some equipment which would have made it easier to control the flow of process steam. The circumstances were exceptional, and I do not criticise anyone concerned in the difficult choice between delaying the availability of the plant and accepting what then appeared to be a small risk of breakdown.

Supervision and Inspection

93. I have been given evidence that there were a few cases of defective workmanship in construction at Tipton. The construction of complex plants of this type clearly demands an exceptionally high standard of supervision and inspection at all levels from the shop floor to the site, and all concerned need to make every effort to maintain the standard required. The practical consequence of undetected faults in construction is to prolong the commissioning period as they come to light.

Some Design Problems

94. Some aspects of the design of the Coleshill and Tipton reformers which have been the subject of review are the following:

(i) **Size of Plant.** It has been stated in evidence to me that there are two advantages in using streams as large as 33 mcfd in comparison with the earlier 25 mcfd streams. There is a saving in capital cost per unit of output of about 10%, and a corresponding reduction in man hours and commissioning effort. No evidence has been brought forward to show that the size of the plant as such had any significant effect on reliability.

(ii) **Potassium carbonate.** The blockage of a naphtha vaporiser at Coleshill in November 1965 was caused by potassium carbonate. The header failures at Coleshill and Tipton were the result of boiler primes, which in turn are attributable to potassium carbonate in the system. It has been made clear to me that other plants outside the West Midlands have suffered from the presence of carbonate in various parts of the system. The carbonate pumps at Coleshill have a history of frequent breakdowns, and cross connection between the streams is not possible when the standby pump is isolated. A combination of these features was responsible for a shutdown during the January crisis. The arrangements for standby equipment at Tipton are different from those at Coleshill.

(iii) **Corrosion.** Serious problems of corrosion were encountered in earlier plant but have now largely been overcome. For instance, the first stream at Coleshill was finally modified for this purpose during the last winter. Materials and design problems have arisen and there is room for continued research into them. I have noted that I.C.I., the Gas Council and plant contractors are co-operating to promote such research.

(iv) **Feedwater supply.** The failure at Coleshill on the night of the 19th/20th January involved a sequence of failures of the pump in service and of the two standby pumps. The initial cause was the presence of large quantities of sludge which blocked the filters at the inlet to the pump. A difficult design decision had been required. If the pumps were protected by coarse filters there would be a danger to bearings and seals: if by fine filters then there would be danger of clogging. In this case the manufacturers recommended fine filters. Although the filters were cleared at proper intervals the system clogged. No completely satisfactory explanation for the presence of this sludge has been given.

(v) **Naphtha heaters.** Apart from the incident in November when a heater at Coleshill was blocked by carbonate, there have been other failures, both in the West Midlands and other Gas Boards. It appears that overheating is liable to follow partial blockage of the heat exchanger. This is often associated with load changes, when the tube ends are more liable to overheat. The naphtha could alternatively be heated by external direct fired heaters, but unless the flue gases were conducted over some other heat exchanger this procedure would involve an economic penalty. Clearly the design of the heaters should be reviewed to see whether reliability can be improved, even with some loss of thermal efficiency in the plant; also whether the design of the tubes could be improved to increase their operating life.

(vi) **Fault analysis in design.** I have noted that the header failures were occasioned by transient conditions in the plant, and this has led me to wonder whether enough thought has gone into defining the worst conditions of temperature and pressure and discovering the actual changes in the chemical process streams when the operating conditions change. I appreciate, however, that there are no absolute rules which can be applied at this stage in design and a large measure of judgment is required.

The Problem of Header Failures

95. Gas coming from the furnace tubes is collected in the header and then passes to the rest of the process vessels. Header temperatures are typically in the region 730–830°C., and in the case of the Coleshill and Tipton plants are about 730°C. In most high-pressure reformers the header is fabricated from a heat resistant alloy. I.C.I. made available to their licensees their own design and the results of their own materials researches.

96. The material adopted almost universally in the U.K. during 1964 and 1965 was a steel with the alloying constituents:

Carbon	0·4%
Chromium	18%
Nickel	37%

It is used in the form of centri-cast pipe. The reason for using this particular alloy was the claim that for the required temperature range it was the cheapest and strongest alloy which could easily be welded.

97. When the Coleshill and Tipton plants were designed, the available experience, as summarised at a conference held at Billingham in October 1964, was that:

(i) I.C.I. were operating seven plants and had discovered cracks in three out of the 14 headers. As a result, the support system was redesigned, and the cracked components were repaired. There had been no trouble following the repairs.

(ii) There had been a complete failure of a header in a gas plant in Sheffield. This was shown to be due to a construction fault, and a repair had since stood up in service.

In short, the material appeared to be satisfactory.

98. There were, however, two important differences between Coleshill/Tipton and the early I.C.I. plants. Firstly, the operating pressures had risen to 400 lb/sq. in. from 150 lb/sq. in. and therefore thicker sections of metal were used and stresses due to heating and cooling would be greater. Secondly, I.C.I. operated with the waste heat boilers connected to a large works steam system. Although I.C.I. have had occasional boiler "primes" their plants have been more stable. At first sight these differences are not large, and are differences in degree rather than in kind; but they seem to be fundamental to the troubles which followed.

99. Since then, in the British gas industry there have been five fractures and two cases of cracking in headers. The fractures were all due to thermal shock. The cause of cracking has not been definitely ascertained but is thought to be corrosion. The fractures include one at Coleshill where the header broke in February 1965, and that at Tipton which is described in Section VI. In four out of the five cases the cause of the thermal shock was a boiler prime.

100. During 1964 a group of organisations, including Humphreys and Glasgow Ltd, I.C.I. and the Gas Council, banded together to sponsor research into this alloy and other cast materials used in reformer furnaces. They sponsored a project at the British Welding Research Association on "The Welding of Cast Austenitic Alloys". In addition to research on welding, the Association investigated failures.

101. This 18/37 alloy "ages" in service. That is to say, it gets harder and stronger. The hardening mechanism is unlike those previously found in this type of alloy and has not yet been fully explained. The practical consequence is that the material behaves in a brittle fashion below a temperature of about 700°C. It follows that the stresses due to a sudden cooling are far more likely to cause failure if temperatures below 700°C are reached.

102. While suspicions were growing during 1965 the first positive communication of these facts to the sponsors was given in December 1965, and the first report of the findings was published in March 1966.

103. While the original decision to use this material was justified on the knowledge then available, it is now clear that such headers are not reliable under conditions where rapid temperature changes may occur. Engineers from the Gas Council have visited the United States and reported on experience with reforming plant in which headers made of this and other alloys have been used. They have recommended that future gas plants should have headers made from alloy to the specification ASTM–B407, which does not embrittle in this way and which has given satisfactory service.

104. However, I have received evidence that I.C.I. are still prepared to use the original material in their own plants. Of the seven new streams they are building, two have centricast 18/37 headers. On the more general question, I understand that cast austenitic alloys are used in quantity in other reformer components, and have been generally satisfactory.

Standardisation

105. I have enquired of witnesses as to the possibilities of standardisation of plants or components as a means of avoiding delays, both in the construction of plants and in their maintenance and repair. I have found a substantial measure of agreement on the following points, which I would suggest as a basis for a concerted approach by contractors and purchasers of reforming plant:

(i) There are a large number of items of equipment which are already, or could readily be made, to standard designs. These include many instruments, pumps, electric motors, valves and other equipment. The standardisation of header materials and sizes is almost completed.

(ii) For heat exchangers, boilers and most pressure vessels the scope for standardisation is limited because improvements in design are continually being made and the duty required is closely related to the individual plant. Nevertheless there must be opportunities for standardisation which would repay exploration.

(iii) For complete plants, the requirements of individual cases vary and there are still divergent opinions on such matters as optimum stream sizes, arrangements of heat recovery trains, use of stainless steel, and other matters which are still under development as operating experience increases. To freeze design too soon would be to forego opportunities of improvement. There may well be increasing scope, however, for repeat orders for plant of types which are known to have given good service.

Manpower

106. Before 1963 the gas industry had few experienced operators and supervisors who had been trained in high pressure processes. In general, there was no source within the U.K. from which fully trained operators could be recruited in the numbers required for expansion. All Gas Boards, including the West Midlands, had to undertake training programmes. The West Midlands Board was lucky in that the Lurgi plant at Coleshill operates at pressure and has some features in common with pressure reformers. This provided one training ground. Personnel were also sent to the Southern Gas Board's reforming plant at Hythe to gain experience. Subsequently, the Coleshill reformers were used for training.

107. The organisation of the Coleshill and Tipton works, in the winter of 1965/66 is given in Appendix 3. I have inspected both works and seen the operation of both plants, and I am satisfied that the Board are achieving an adequate standard of operation and supervision. Moreover, the experience of rapid shutdowns and emergencies which their operating staff have had should help them to cope with any similar problems in the future.

Commissioning

108. A matter on which I have not been satisfied is the commissioning of new plant. Plants are normally intended to be in operation in time for the winter demand, and consequently there is a tendency to let contracts so that mechanical completion is due in the autumn. It is becoming very generally appreciated, however, that it is an essential requirement in construction of new plants that they should be finished well before they are needed for production, to allow an adequate period for commissioning. This period should be about three months, in my view, to provide reasonable certainty of the availability of the plant for production when it is needed.

109. It is during the commissioning period that operating problems are most difficult. Most header failures, for instance, have occurred early in the life of the plants concerned. Such incidents occurred at both Coleshill and Tipton while the plant was under the direction of Humphreys and Glasgow's commissioning engineer. In view of this, it is essential for the commissioning engineer and his assistants to be men of experience and accustomed to dealing with the unexpected. In the particular case of Tipton there may well have been unusual commissioning problems arising out of the short cuts I have referred to in para. 92

110. Humphreys and Glasgow Ltd have told me that because the commissioning of nearly all new plant is required at about the same time, in the autumn, they have difficulty in finding enough suitably qualified engineers for this when they are needed. I have received evidence that in fact there is a national shortage of the type of people required for this work, and other contracting organisations share this problem. Humphreys and Glasgow Ltd have written to the Gas Council on the subject, in the hope that a way can be found of spreading the commissioning load over a longer period of the year.

111. Humphreys and Glasgow's commissioning engineer at Tipton was a senior man with many years experience of operating plant and three years experience of reformers. To support him were three two-man teams, each of one engineer and one shift operator—one team per shift. The operators had previous experience of reformers. Assisting the commissioning team were the Board's own station operating staff and four new graduate engineers whose services had been made available to Humphreys and Glasgow Ltd by the Board.

112. The prospects for the future may be somewhat brighter. Now that all Boards have some properly trained reformer crews they are in a position to help themselves over both training and operating in a way which was not possible earlier. The situation during 1965 was perhaps the worst which will be reached. Possibly more use could be made of special technical aids, such as simulators, for training commissioning and operating teams.

113. Turning now to contractual aspects of commissioning, it is clearly essential that the task of the commissioning engineer should be specified in the contract as precisely as possible. I understand that the contracts for Coleshill and Tipton did not include a definition of the scope of commissioning trials. Contract completion dates referred to mechanical completion of the plant. Owing to the shortage of commissioning staff, Humphreys and Glasgow Ltd now include only the services of the commissioning engineer in new contracts, other staff being offered on a cost-plus basis as required.

114. I am informed that the standard conditions of contract, prepared by the Gas Council and the Society of British Gas Industries, are being revised. I would urge that the standard conditions should include a procedure for defining commissioning tests in detail, bearing in mind that commissioning is a lengthy procedure.

Maintenance

115. I have considered whether the Board's maintenance organisation might be at fault. Evidence has been received that the Board is not short of skilled men for maintenance purposes, and that they are able to keep enough people in spite of the high wages paid by local industry.

116. There is a central maintenance organisation which covers planned maintenance and instrument repair. Men are also employed locally at each works. I am satisfied that the organisation is adequate. I have also inspected the workshops and stores and am satisfied that these are adequate.

117. I have received evidence that over the crisis the staff worked very long hours and that most were short of sleep for its duration; much of the work had to be done out of doors in bad weather, and their devotion to duty was exceptional.

118. I have concluded that the maintenance organisation had adequate facilities of men and equipment for repairs under normal conditions, but that insufficient spare plant was available for them to operate effectively.

Reliability

119. I have been concerned to answer two questions:

(i) Are the plants sufficiently reliable for general use in the gas industry?

(ii) Is there anything particularly unreliable about the plants in use in the West Midlands?

120. Evidence has been given that modern chemical plant using similar equipment and operating under conditions similar to those in pressure reformers can be expected to produce during the first year of operation only about 60% of the possible end-product. The reasons lie partly with the operators, and partly with the equipment. It is clear that the first year must be regarded as an extension of the commissioning period during which tecthing troubles are to be expected and must be overcome. One witness stated that in the chemical industry no commercial production should be relied upon from large high-pressure installations during the first three months.

121. The availabilities of reforming plants constructed by Humphreys and Glasgow Ltd, and similar to those at Coleshill and Tipton have been given as:

46, 48, 48, 50, 54, 57, 81, 100%—an average of 61%

during the first three months of operation. After the first year, 97% availability should be expected, if planned overhaul periods are excluded.

122. The following table shows the availability of reformers in use in the U.K. gas industry during the winter of 1965/66. Returns from earlier periods are not available in this form.

Period	Availability (per cent)	
	11 Area Boards	W.M.G.B.
30.11—17.12	93·5	87·5
20.12—10.1	93·5	76·0
11.1 —28.1	96·2	54·0
31.1 —17.2	96·2	84·0

123. The West Midlands show figures below those for the rest of the country. Considering the plants individually:

(i) The first stream at Tipton made gas for the first time on 29th November 1965. During its first three months its total availability was 57%. This figure includes the time taken to replace the broken header.

(ii) The second stream at Tipton made gas for the first time on Thursday, 20th January 1966.

(iii) The first stream at Coleshill made gas for the first time in December 1964, and for its first three months had an availability of 81 %. Following its annual overhaul in the autumn of 1965, the availability was 89 % up to 26th February 1966.

(iv) The second stream at Coleshill suffered from a broken header on 24th February 1965. A fire ensued and the plant was not returned to work until 7th August, 1965. From then until 26th February 1966, excluding scheduled shutdowns for modification and inspection, the availability was 92 %.

124. Headers have been discussed elsewhere. Apart from that question, the availability of the Coleshill plants still appears to be marginally lower than might be expected. From Wednesday, 19th January, until Friday, 28th January, while the crisis was at its height, both the Coleshill streams were intermittently off the grid due to a variety of breakdowns. I have compared these and the other failures at Coleshill with an analysis of faults which the Gas Council compiled as a result of the first year's experience of reformers. Apart from the incident when naphtha superheaters were blocked by potassium carbonate, there are no faults which have not occurred on other plants. It is noticeable that breakdowns in both naphtha superheaters and carbonate pumps occurred more than once during the winter. These two items have been discussed in paragraph 94.

125. I conclude that the answers to the questions set out in para. 119 are firstly, that this type of plant is intrinsically reliable and generally suitable for the gas industry: and secondly, that the West Midlands plants did not deviate greatly in their behaviour from similar plants elsewhere. It was unfortunate that the breakdowns coincided, and occurred during a period of cold weather.

126. The cause and the seriousness of this piling up of trouble lies in the shortage of capacity. The picture presents itself to me of a situation where any shutdown could lead to crisis.

VIII. OUTLOOK FOR THE FUTURE

127. The Board's forecast, made in March 1966, of the demand for gas on a peak day at an average temperature of 35°F. at the beginning of November 1966 (the probability of this is estimated as one winter in twenty) is 429 mcf. Their forecast of demand on a peak day at 24°F. in January 1967 (probability also one winter in twenty) is 545 mcf.

128. To meet the November peak demand of 429 mcf. the planned production capacity is now 483 mcfd—a margin of 54 mcf. This capacity includes the whole of the Tipton I plant, which by then will have been in operation for over seven months, and allows for the closure of some worn-out carbonising plant.

129. To meet the January peak demand of 545 mcf. it will be necessary to complete and commission at least a substantial part of the new reforming plants which the Board has under construction, namely:

Stoke-on-Trent: two streams scheduled for mechanical completion 31st October and 31st December:	40 mcfd
Tipton II: three streams scheduled for mechanical completion 1st October, 1st November, 1st December:	100 mcfd

I understand from the Board and contractors that delays in obtaining certain equipment for these plants are likely. If a sufficient number of the streams now under construction are not completed before any severe weather occurs the Board's security of supply will be at risk.

130. As a partial insurance against delay or breakdowns the Board has put in hand during the current year the construction of a 15 mcfd cyclic (low-pressure) reforming plant of a type which has been found particularly reliable and to require only a short commissioning period. Completion is due by the 1st January 1967. This is clearly a prudent step, but in my opinion the Board and its contractors will need to make a strenuous effort to complete and commission the new high-pressure reformers in good time if they are to be able to rely on their own gasmaking resources. My view is based on both the threat of delays and the consideration that full output should not be relied on from the new plants in their early months. If all the projected capacity is completed on time, and if commissioning can be complete in two months from mechanical completion of the plants (in my view it is unlikely to take less), the capacity available by mid-January to meet a peak demand of 545 mcf. will be

$$483 + 20 + 67 + 15 = 585 \text{ mcfd}$$

assuming 100% availability. If however the new high-pressure plants were to give only 50% availability at this early stage the capacity which could be counted on would be only

$$483 + 10 + 33 + 15 = 541 \text{ mcfd}$$

—without any allowance for the possibility of breakdown of older plants.

131. I therefore commend the additional step which the Board is taking in installing a high-pressure pipeline link between its own supergrid and that of the neighbouring East Midlands Gas Board, for mutual support in case of shortage on either side. This is to be completed by the winter of the current year, and is to be capable of transferring up to 100 mcfd in either direction. It would not, of course, provide any insurance against simultaneous shortage on both sides.

132. I understand that the Board has imposed some checks on the current growth of demand during the present year, by refusing new industrial space heating loads and postponing the fixing of gas fires.

133. In the longer term, the Board can expect to be in a more secure position as a result of additional reforming capacity and the prospect of supplies of natural gas from the North Sea, but at least for the next year or so it seems unlikely that any relaxation of effort will be possible.

IX. GENERAL APPRAISAL AND SUMMARY OF CONCLUSIONS

134. In the late 1950's it became possible to make gas much more cheaply from petroleum feedstocks than from coal. There were two main reasons for this, namely, the availability of cheap naphtha and the development of processes capable of converting naphtha into gas which could be used by the gas industry.

These processes not only produce gas cheaply but also produce it at high pressure which makes distribution easier. They were seen to be a real break-through in the problem of combating rising costs in the gas industry.

135. By 1962, the gas industry was making plans to change over from carbonisation to these new processes, enriching the gas to town gas standards with butane, rich gas produced by hydrogenators, or methane which would become available from the Gas Council's scheme to import liquefied natural gas from Algeria. The new processes were, however, of a type unfamiliar to the gas industry.

136. Throughout the 1950's the demand for gas was, if anything, declining in the face of competition from other sources of heat, but in 1960 there was a growing demand by the public for warmer homes and a large share of this increase in demand for fuel has been taken up by the gas industry.

137. The rapid rise in demand for gas, coupled with the length of time needed to design and construct large and complex plant, presented those responsible for forward planning with a difficult task.

138. Two factors which only became apparent later hindered the realisation of the plans of the West Midlands Gas Board. The first was that by using this new type of gasmaking plant the Board was entering into the petro-chemical industry where plant construction was soon not able to keep pace with the rapid increase in demand, because too heavy a burden was being thrown on the manufacturers of component parts. The effect of this throughout the country has been to delay completion of plants. The second was that the Board was accustomed to very high reliability from coal carbonising and water-gas plants. There was no experience at that time that plants of the new type could not be relied on for more than a fraction of their rated output during the early months of their life. In fact, the complexity of these plants led to "teething troubles", and only when these were overcome could a high degree of reliability be expected.

139. The responsibility of deciding on the amount of plant to be installed to meet forecast demands rested with the Board and not the Director of Gas Supplies. I have received no evidence of failure by any of the Board's officers to do his utmost to achieve the Board's plans.

140. The fluctuating loads which the gas industry has to meet and meet with reliability do not make economic planning easy. They not only vary greatly between summer and winter, but also between mild and severe winters. This means that there are bound to be standby plants, idle for much of the year. Pipeline linkage between Boards is one way of spreading the load and making more use of standby plants.

141. In sections II to VII of this report I have given the detailed results of my investigation. A summary of my principal conclusions is as follows:

(i) The provision of gasmaking plant in the Board's 1964 Capital Development Programme allowed too small a margin for the winter of 1965/66.

(ii) New gasmaking plant ordered for operation at Tipton was late in mechanical completion and commissioning, so that the Board was not able to achieve the total capacity planned for the winter of 1965/66.

(iii) The gas shortage in the period 15th to 17th November was caused by the coincidence of a period of exceptionally cold weather with loss of some gasmaking capacity due partly to a breakdown of high pressure reforming plant at Coleshill. The shortage of gas production capacity forced the Board, in the interests of public safety, to reduce gas supplies to consumers.

(iv) The gas shortage in January 1966 was more serious and arose from combination of plant shortages and breakdowns extending from the 10th to the 30th January which coincided with a period of severe weather. The aggregate shortfall in gas supply over the period was about 700 million cu. ft.

(v) The Board did everything in their power throughout the shortages to ensure that the burden on consumers was shared as fairly as possible and, with full co-operation from contractors and manufacturers of equipment, to restore gas supplies. Because of the virtual impossibility of cutting off gas supplies to domestic consumers, the burden of the shortages fell mainly on industry.

(vi) The I.C.I. high pressure continuous naphtha reforming process used in the Coleshill and Tipton plants is generally reliable and suitable for use by the gas industry. It is used extensively in the gas and chemical industries in the U.K. and abroad.

(vii) The Board made no error of judgment in selecting Humphreys and Glasgow Limited as the main contractors for the construction of the Coleshill and Tipton reforming plants. There was good co-operation between the Board and the contractors.

(viii) The completion of the Tipton plant was late. Fabricators and equipment manufacturers under sub-contract to the main contractors had difficulties and the delay was aggravated by faults in some equipment and concentration of effort on completing the first stream.

(ix) In January, the Board needed the full output from all its plant, including 100 mcfd from Tipton, to meet the demand at a temperature of 25°F. However, only the first of the three streams there had been completed and it suffered from successive failures culminating in a broken header pipe. The second was started but had to be shut down almost immediately. The third was not completed until March. The situation was aggravated by breakdowns of the Coleshill reformers during the night of the 19th January.

(x) Several header failures have occurred in the gas industry. The basic cause is that rapid temperature changes in the plant have over-strained the material. A different material which can withstand these conditions has been recommended. Research is continuing on an industry-wide basis.

(xi) There is also a need for various improvements in the design of reforming plant. Certain weaknesses in earlier designs are now recognised and are being eliminated in future plants.

(xii) Some improvement in the position should be possible by standardising some features of the design of reforming plants. It would not be wise at the present stage of experience, however, to standardise the design of the entire plant.

(xiii) The gas industry and plant contractors are short of skilled and experienced engineers and operators for commissioning new plants. This problem is aggravated by the tendency for new plants to be scheduled for completion in the late autumn. The commissioning team at Tipton were competent, but insufficient time was available for their work.

(xiv) Gas Boards and contractors should agree on an adequate commissioning period under the contractor's control before new plants are handed over to the Boards' operating staff. A period of about three months would be reasonable.

(xv) The maintenance organisation of the Board had adequate facilities of men and equipment for repairs under normal conditions but insufficient spare gasmaking plant was available for it to operate effectively.

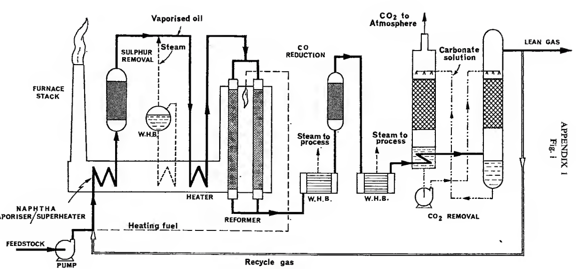
142. In Section VIII I have commented on the outlook for the future.

R. M. Wynne-Edwards
4th July 1966

L. J. Jolley
Eric J. Walters
(Joint Secretaries)

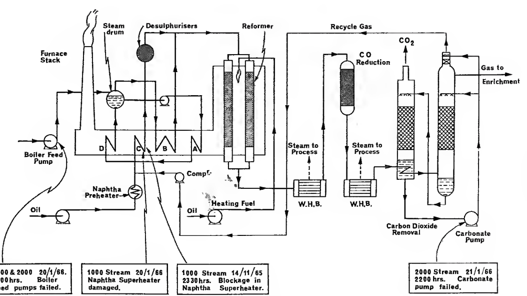
APPENDIX 1

Fig. i



SIMPLIFIED FLOW DIAGRAM OF I.C.I. REFORMER

APPENDIX 1
Fig. ii



1000 & 2000 20/1/66. 0100 hrs. Boiler feed pumps failed.

1000 Stream 20/1/66 Naphtha Superheater damaged.

1000 Stream 14/11/65 2330 hrs. Blockage in Naphtha Superheater.

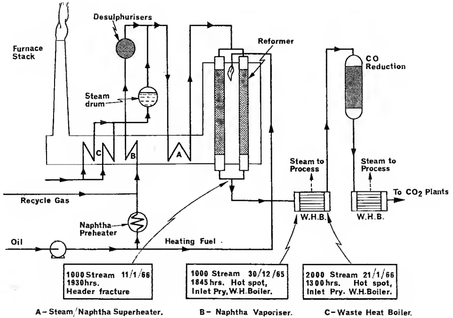
2000 Stream 21/1/66 2200 hrs. Carbonate pump failed.

A – Waste heat boiler. (shock bank)
B – Steam superheater.
C – Naphtha Superheater.
D – Waste heat boiler. (back boiler)

COLESHILL

APPENDIX 1

Fig. iii

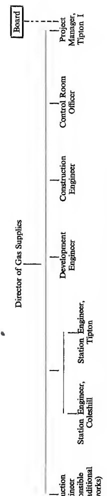


1000 Stream 11/1/66
1930hrs.
Header fracture

1000 Stream 30/12/65
1845 hrs. Hot spot,
Inlet Pry, W.H.Boiler.

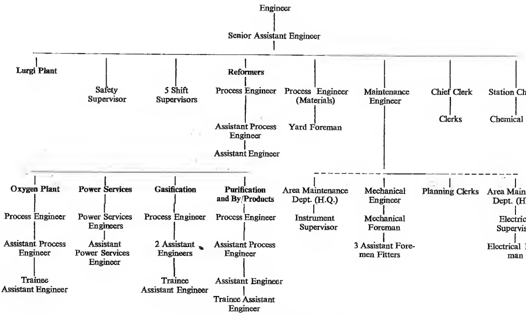
2000 Stream 21/1/66
1300 hrs. Hot spot,
Inlet Pry. W.H.Boiler.

TIPTON I



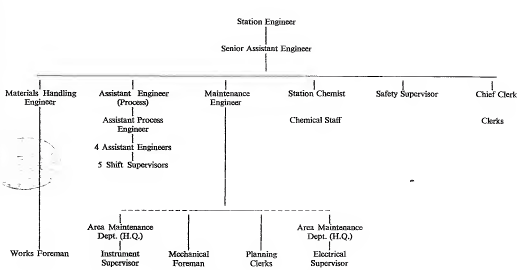
ORGANISATION OF GAS SUPPLIES IN THE WEST MIDLANDS
(WINTER 1965/66)

APPENDIX 3



ORGANISATION OF COLESHILL WORKS
(WINTER 1965/66)

APPENDIX 3



ORGANISATION OF TIPTON WORKS
(WINTER 1965/66)

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MINISTRY OF POWER

Report on Shortages of Gas Supplies in the West Midlands During the Winter of 1965/66

by
SIR ROBERT WYNNE-EDWARDS
C.B.E., D.S.O., M.C., M.A., M.I.C.E.

LONDON
HER MAJESTY'S STATIONERY OFFICE
1966

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